An Inter-granular Giant Magnetoresistance Effect in a Spontaneously Phase Separated Perovskite Oxide

J. Wu[1], J.W. Lynn[2], C.J. Glinka[2], J. Burley[3], H. Zheng[3], J.F. Mitchell[3], W.G. Moulton[4], M.J.R. Hoch[4], P.L. Kuhns[4], A.P. Reyes[4], and Chris Leighton[1]

[1] *University of Minnesota, Minneapolis, MN 55455*
[2] *National Institute for Standards and Technology, Gaithersburg, MD*
[3] *Materials Science Division, Argonne National Laboratory, Argonne, IL*
[4] *National High Magnetic Field Laboratory, Tallahasse, FL*

We report recent results on the investigation of magnetic phase inhomogeneity in doped perovskite cobaltites. These cobaltite materials have been the focus of far less research than the analogous manganites [1,2], despite the existence of unique phenomena that cannot be accessed in manganites and cuprates. Undoped cobaltites such as $LaCoO_3$ have been studied since the 1950's [3] due to the existence of thermally driven spin-state transitions which result in a crossover from diamagnetic to paramagnetic with *increasing* temperature. This flexibility with respect to the spin-state adopted by the Co ions is due to the comparable sizes of the Hund's rule exchange energy and crystal field splitting and leads to a spin-state degree of freedom in addition to the competition of spin, charge, orbital and lattice correlations that occur in manganites.

Recent work has led to the realization that these cobaltites display a particularly clear form of magnetic phase separation and that they possess certain simplifying features that allow them to be employed as model systems for the investigation of magnetic phase inhomogeneity. This magnetic phase separation phenomenon [4] involves the formation of a spatially heterogeneous magnetoelectronic state even in the absence of chemical inhomogeneity, and is thought to play a crucial role in important phenomena of contemporary interest such as colossal magnetoresistance, high temperature superconductivity, and multiferroics.

Previously, using ^{59}Co NMR we have demonstrated that $La_{1-x}Sr_xCoO_3$, a canonical example of a doped cobaltite, displays spatial coexistence of low spin, spin-glass and ferromagnetic phases at all compositions, as shown in Figure 1 [5]. In this work

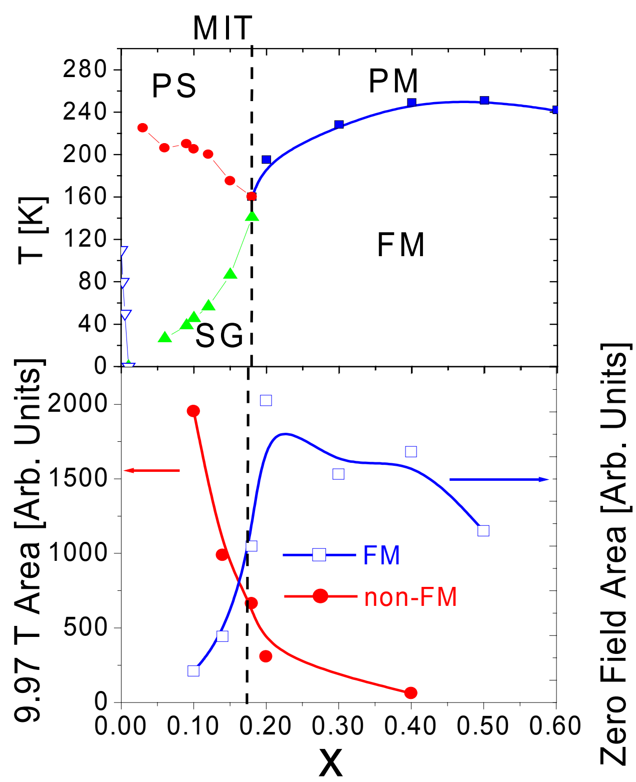

Figure 1.(a) Magnetic phase diagram of $La_{1-x}Sr_xCoO_3$ **(b)** x dependence of the ferromagnetic and non-ferromagnetic phase fractions.

we present complementary Co NMR, La NMR and small-angle neutron scattering data proving that, at low Sr doping, $La_{1-x}Sr_xCoO_3$ phase separates into ferromagnetic metallic clusters embedded in a non-ferromagnetic semiconducting matrix. With increasing doping these clusters coalesce leading to percolation and the simultaneous onset of long-range ferromagnetic ordering and metallic behavior [6]. Most interestingly, the formation of ferromagnetic clusters embedded in a non-ferromagnetic matrix induces a large negative hysteretic magnetoresistance, with temperature and field dependence characteristic of an inter-granular Giant MagnetoResistance (GMR) effect. The MR (Figure 2) is found to occur only in the presence of isolated ferromagnetic clusters, disappearing when the clusters coalesce at the percolation transition (i.e. x = 0.18, see inset to Figure 2). We argue that this system is a naturally forming analog to the artificial structures fabricated by depositing nanoscale ferromagnetic particles in a metallic or insulating matrix, i.e. this material displays a GMR effect without the deliberate introduction of chemical interfaces.

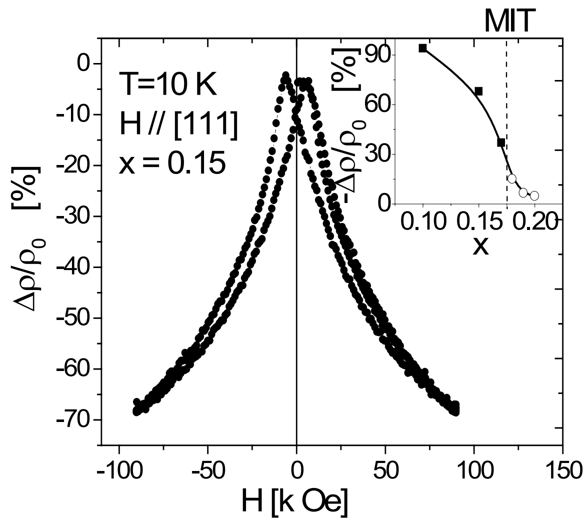

Figure 2. 10 K magnetoresistance (MR) for x = 0.15. **Inset:** x dependence of the 90 kOe MR.

Work supported by US DoE (ANL) and the Petroleum Research Fund (UMN)

References

[1] J.M.D. Coey, M. Viret and S. von Molnár, "*Mixed-valence manganites*", Adv in Phys. **48** 167 (1999).

[2] Y. Tokura and Y. Tomioka, "*Colossal magnetoresistive manganites*", J. Mag. Mag. Mat. **200** 1 (1999).

[3] Short review - M. Imada, A. Fujimori and Y. Tokura in *Metal-Insulator Transitions*, Rev. Mod. Phys. **70** 1039 (1998). p 1235-1239.

[4] E. Dagotto, T. Hotta and A. Moreo, "*Colossal magnetoresistant materials: the key role of phase separation*", Phys. Rep. **344** 1 (2001).

[5] P.L. Kuhns, M.J.R. Hoch, W.G. Moulton, A.P. Reyes, J.Wu and C. Leighton, "*Magnetic phase separation in $La_{1-x}Sr_xCoO_3$ from ^{59}Co NMR*", Phys. Rev. Lett. **91** 127202 (2003); M.J.R. Hoch, P.L. Kuhns, W.G. Moulton, A.P. Reyes, J. Wu and C. Leighton, "*Spin dynamics in $La_{1-x}Sr_xCoO_3$*", Phys. Rev. B., **69** 014425 (2004).

[6] J. Wu and C. Leighton, "*Glassy ferromagnetism and magnetic phase separation in $La_{1-x}Sr_xCoO_3$*", Phys. Rev. B. **67** 174408 (2003).